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Differing modes of animal exploitation in North-Pontic Eneolithic and Bronze Age Societies

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ABSTRACT
This paper presents new results of an interdisciplinary investigation of the diet and subsistence strategies of populations living in the North-Pontic region during the Eneolithic and the Early Bronze Age (ca. 3800 BC to the 2500 BC). New organic residue analyses of >200 sherds from five Eneolithic sites and two Early Bronze Age settlements are presented. The molecular and stable isotope results are discussed in relation to zooarchaeological evidence. Overall, the findings suggest that each community relied on either a hunting- or a husbandry-based subsistence strategy dependent upon the ecosystem in which they settled; horses and wild animals dominated subsistence in the forest-steppe communities in contrast to ruminant husbandry in the steppe.

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Prehistoric North-Pontic region; animal exploitation; organic residues; carbon isotopes

1. Introduction

The vast Eurasian steppe belt has been studied by many scholars, and the exploitation of this arid zone in late prehistory has been a subject of particular interest for western researchers over the last two decades (Boyle, Renfrew, and Levine 2002; Levine, Renfrew, and Boyle 2003). The various innovations discussed as originating in the Eurasian steppe zone, for example ox-drawn wooden wagons with four solid disc wheels, horse domestication and cord ornamentation on vessels, have attracted the attention of many archaeologists (Kuzmina 2003; Sherratt 2003; Harrison and Heyd 2007). The Eurasian steppe zone is often considered as a "zone of contact" between various cultures of Europe and Asia. Innovations were transferred over vast distances from east to west and vice versa. During the last two years, new palaeogenetic evidence has been uncovered indicating migrations from the steppe to Central Europe involving a substantial number of people (Haak et al. 2015; Allentoft et al. 2015). This reinvigorated the controversial debate surrounding the homeland of Proto-Indo-European language. Several scholars have interpreted the new palaeogenetic data as supporting the hypothesis that the original speakers of PIE lived the western part of the Eurasen steppe (Kristiansen 2014 for a critical approach cf. Heyd 2016; Kaiser 2017).

The introduction of specialised animal husbandry and the emergence of mobile pastoralism, often assumed to be closely connected with that introduction, still thought to constitute one of the early and highly influential innovations that took part in the Eurasian steppe zone (Merpert 1974; Kuzmina 2003; Anthony 2007). Although there been a tendency to consider the Eurasian steppe belt as a uniform ecosystem, it is indeed very diverse, stretching from Moldova and Ukraine in the west, to Mongolia in the east. The Ural Mountains can be considered as a natural border that divides this vast area into two very different ecosystems: the western Pontic region and the eastern Eurasia, each characterized by diverse soils, climatic zones, vegetation and faunal composition. The forest-steppe forms a transitional vegetation zone (ecotone according to Walter and Breckle 1977) between the steppe in the south and the forest in the north. This holds true for the region north of the Black Sea. Climatic features, vegetation and faunal composition change depending on the proximity to the Dnieper River, which is the main river that bisects the region, from north-west to south-east, and to the Black Sea, which is the southern border of the region.

The current study aimed at deepening the knowledge of the subsistence economy and lifestyle of the ancient societies that populated the Eneolithic and Bronze Age periods (ca. 3800-2500 BC) in the North-Pontic region. This period is characterized by transitions and changes: around 3100 BC a remarkable change in the burial practices can be observed. With

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the beginning of the Yamnaya culture in sensu stricto, the number of burials increases significantly. Grave construction and burial rites became far more homogeneous than they were in the 4th mill. BC. All graves of the Yamnaya culture are situated in or under a burial mound. The deceased were buried in a crouched position and often covered with ochre. The graves and most of the inventory objects are very similar over the very large area of the culture's dissemination, which stretches from the Transurals in the east to the Lower Danube in the west. Unfortunately, only a small number of settlements are known, most of them concentrated on the banks of the rivers Dnieper, Severskiy Donets and Don (Kaiser n.d.). Thus, reconstructions relating to the Yamnaya population are based (almost solely) on the interpretation of data from their graves.

Nevertheless, social and economic changes were reconstructed to have taken place during the 4th and the 3rd millennium BC: 'A special type of economy - the pastoralism - with herding predominant has formed in the steppe' (Kuzmina 2003, 203). However, zooarchaeological evidence is particularly scarce in this area and during this period, which means that the extent of animal domestication and dietary habits of the North Black Sea communities remain poorly understood. Consequently, there is an ongoing discussion concerning several aspects of the subsistence economy (Rassamakin 1999, 129–32).

It is believed that the transition to food production in North-Pontic region followed a trajectory different to that of the Central European Neolithic and Bronze Age and that 'the agricultural revolution took the character of stock-breeding' (Renfrew 2002). Domesticated cattle, sheep and goat are believed by many scholars to have appeared in the North-Pontic region at around the 6th millennium BC (Bunyatyan 2003; Kotova 2003; Kotova and Makhortykh 2010); the relatively late introduction of animal husbandry has been linked to environmental conditions in the steppe (e.g. Wechler 2001).

Lillie and Jacobs (2006) had previously emphasised the variability in access to dietary protein sources of the Mesolithic populations located in the Dnieper region (e.g. Lillie 1998; Lillie 2003; Lillie and Jacobs 2006). Specifically, they carried out stable isotope analysis on human, fauna and fish bones recovered from Neolithic and Eneolithic cemeteries located in the Middle and Lower Dnieper Basin of Ukraine (Lillie, Budd, and Potekhina 2011). The latter study supported a diet mainly based on C_3 terrestrial foodstuffs, supplemented with aquatic resources, such as freshwater fish. Nevertheless, reconstructing the subsistence economy and dietary habits of populations during a period of economic and social changes is challenging. The current picture is that the extent of animal domestication in this region is poorly defined. Our recent paper (Mileto et al. 2017) revealed that the Mid-Eneolithic community of Dereivka (located in the forest-steppe along the Dnieper River) consumed predominantly equine products, together with smaller proportions of ruminant carcass products; no evidence for ruminants dairy processing could be seen in the cooking residues from pottery. The abovementioned results generally supported the previous bulk stable isotope investigations of human bones recovered from the Neolithic cemetery of Dereivka (Lillie, Budd, and Potekhina 2011). Further research in the North Black Sea region (e.g. Rassamakin 1999; Renfrew 2002; Kuzmina 2003; Bunyatyan 2003; Bendrey 2011) emphasized the importance of considering the influence of each regional ecosystem independently, since the adaptations of the lifestyles of the resident populations would have depended on the characteristics of the local environment. The current literature (Rassamakin 1999; Kuzmina 2003; Lillie, Budd, and Potekhina 2011; Mileto et al. 2017) strongly supports the hypothesis of interchangeable strategies of husbandry-hunting, dependent upon the regional ecosystems, which would have been very different in southeast compared to the northwest of the North Pontic (Kremenetski 2003).

Herein, we present the results of organic residues analysis of 216 potsherds from three Mid-Eneolithic sites (Dereivka, Molyukhov Bugor and Mikhailovka I), two Late-Eneolithic sites (Mikhailovka II and Nizhniy Rogachik) and two Early Bronze Age settlements (Mikhailovka III and Generalka). These results provide opportunities to test the hypotheses that: (1) a new form of subsistence economy, pastoralism, was introduced in the North-Pontic region at around the 3rd millennium BC, and (2) that animal exploitation and dietary habits were likely driven by the local environment. These sites were chosen on the basis of their geographical location (forest-steppe *versus* steppe sites; Figure 1). The findings from the lipid biomarker and stable isotope results are interpreted in relation to previously published zooarchaeological studies (Telegin 1986; Rassamakin 1999; Kaiser 2010; Zhuravlev & Markova 2000; Zhuravlev 2008).

2. The settlements

The investigated sites (Dereivka, Molyukhov Bugor, Mikhailovka I-II and III, Nizhniy Rogachik and Generalka) belong to three different cultures as shown in Table 1 (Rassamakin 1999). The Nizhniy Rogachik site has yet to be fully assigned to any of the known cultures. One of the excavators of the site, O.G. Shaposhnikova specifically named these materials as Rogachik type and dated them Late Eneolithic (contemporaneous to Late Tripolye period; Shaposhnikova 1972); therefore, it is possibly contemporaneous with Mikhailovka II (Spitsyna 2010). Generally, defining the

Table 1. Cultures and sites analysed in the current project.

Culture	Sites	Location	Periods
Dereivka	Dereivka and Molyukhov Bugor	Forest-steppe region	Ca. 3800-3500BC
Nizhnaya (Lower) Mikhailovka	Mikhailovka I	Steppe region	Ca. 3800-3000BC
Repin Rogachik type	Mikhailovka II and Nizhniy Rogachik	Steppe region	Ca. 3500-3000BC
Yamnaya	Mikhailovka III and Generalka	Steppe region	Ca. 3000–2300BC

chronology of Ukrainian sites is controversial; indeed, despite performing a consistent number of radiocarbon analysis (Telegin et al. 1986; Anthony & Brown 2003; Kotova & Videiko 2003; Kotova & Spitsyna 2003; Kotova 2008) the peculiar type of soil (*Chernozem*) obscures the archaeological layers producing a mixture of materials and introduces chronological uncertainties. As a consequence, common chronological subdivisions do not exist. Therefore, the current reconstruction is mainly based on the work of Rassamakin (1999) who proposed the chronology of the five sites and investigated potsherds based on existing radiocarbon analyses (Rassamakin & Kaiser n.d.) and ceramic features (i.e. decoration, ceramic matter, etc.). This cultural and chronological reconstruction forms the basis of the following discussions.

The Dereivka and Molyukhov Bugor sites are located in the forest-steppe area of the modern Cherkassy Region (Figure 1). The Dereivka settlement was situated on a promontory of the River Omelnik, a tributary of the Dnieper River. It is the best-investigated North-Pontic settlement of the Eneolithic (Telegin 1986); nevertheless, many questions remain concerning the chronology, subsistence economy and the status of horse domestication, amongst the community who inhabited this settlement (Levine 1990; Rassamakin 1999; Mileto et al. 2017). The Molyukhov Bugor site was part of Dereivka culture (Rassamakin 1999) and was located on the Dnieper River, near the village of Novoselitsa, Chigirin District (Kotova 2003; Neradenko 2013). Both of these forest-steppe sites were highly influenced by the neighbouring communities of the Tripolye culture, as suggested by several imported materials (Rassamakin 1999).

Contemporaneous with Dereivka and Molyukhov Bugor sites is the earlier layer of Mikhailovka (Rassamakin 1999). The two later Mikhailovka horizons date to the Late Eneolithic (II) and Early Bronze Age (III). Due to overlap of the two later horizons (II and III), the archaeological materials recovered from these layers have always been considered together, which complicates interpretations and dating. Overall, the Nizhnaya (Lower) Mikhailovka culture was influenced by Eneolithic western societies, including the Cucuteni-Tripolye culture, represented by numerous burials in kurgans located between the Molochnaya River and Danube (Rassamakin 1999: 92); the investigated sherds have been recovered from the lower horizon of Mikhailovka settlement on the lower Dnieper River.

The Late-Eneolithic Nizhniy Rogachik settlement was located on a plateau above River Konka and Dnieper (Telegin 1957; Shaposhnikova 1963; 1972; Spitsyna 2010). In comparison with the other investigated sites, the information about this settlement is extremely scarce.

Finally, the site of Generalka was located on the Khortytsia Island (Zaporozhia city). The settlement is

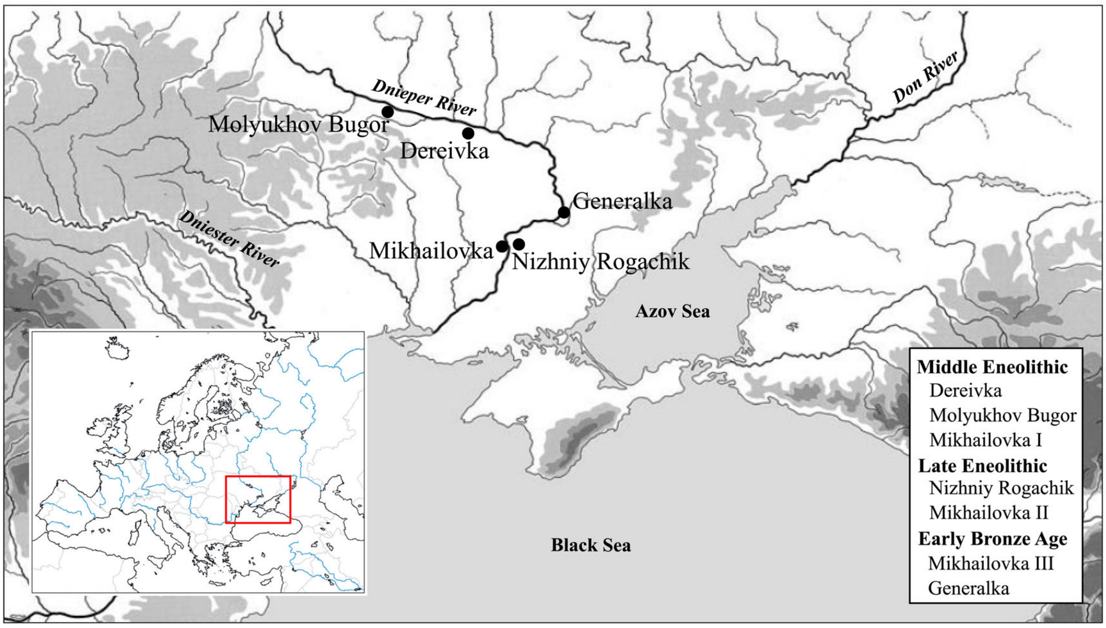

Figure 1. Map of the North-Pontic region showing the distribution of the five settlements investigated in the current study.

relatively extensive, covering an area of ca. 7000 m^2, although only ca. 300 m^2 have been excavated. Thus, the information related to the Generalka community should be regarded as preliminary (Tuboltsev 2006, and internal reports); however, zooarchaeological analysis of the available material has been performed by M. Hochmuth from the German Archaeological Institute, Berlin (Kaiser 2010). Figure 2 displays few examples of analysed sherds and typical vessels shape from each site.

3. Archaeozoological evidence

Figure 3 presents the number of identified specimen (NISP%) of the different classes of animals. The latter are adapted from Kaiser (2010). The two Mid-Eneolithic faunal assemblages of Dereivka and Molyukhov-Bugor are dominated by wild animals and horses, 17% and 60%, respectively, for Dereivka, and 37% and 14%, respectively, for Molyukhov-Bugor. However, Molyukhov-Bugor faunal records also comprised a 49% of domesticated animals. In contrast, the Eneolithic and the Early Bronze Age steppe faunal records revealed that the majority of the faunal assemblages comprise domestic ruminants. Significantly, sheep and goats dominate the earlier horizon of Mikhailovka (65%), while the later horizons are dominated by cattle (59%). In general, wild animals were identified in all the settlements under study, including ruminant (e.g. European red deer, saiga-antilopes) and non-ruminant game (e.g. beaver, hare).

4. Methodologies

The analytical protocol followed has been described in detail in earlier papers (Evershed et al. 1990; Charters et al. 1993; Dudd & Evershed 1998; Copley et al. 2003). Lipid concentrations in cooking vessels are generally highest in rim or upper-body sherds, so these were selected wherever possible from vessel types likely to have been used for processing food, therefore with signs of cooking activities (e.g. charring and sooted). After cleaning, approximately 2 g samples of the potsherds were crushed with the lipids extracted with organic solvent by ultrasonication, yielding a total lipid extract (TLE). Aliquots of the TLEs were trimethylsilylated prior to gas chromatographic (GC) screening and GC-mass spectrometry (GC-MS). A further aliquot of the TLE was saponified and fatty acid methyl esters (FAMEs) prepared. These FAMEs were analysed by GC–combustion–isotope ratio MS (GC-C-IRMS) to determine compound-specific $\delta^{13}C$ values.

The fats extracted from the pottery vessels were classified to principal commodity group by plotting their $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values. Assignments were reached through the comparison of the $\delta^{13}C$ values with those obtained from modern reference fats. Due to the absence of modern Ukrainian reference isotope values, the identification of the archaeological fats were mainly achieved by comparing the stable carbon isotope composition of the archaeological fats with those of the modern fats from Kazakhstan (in Figures 5 and 6, the ranges defined with dotted lines; Stear 2008); however considering the very different environment of Kazakhstan comparing to Ukraine, the first 'universal' plot created by using a global reference database of modern fats (in Figure 5 and 6, the ranges defined with solid lines; Salque 2012) has been overlapped to the Kazakh template plot. In addition, in order to allow a better fat assignment, the $\Delta^{13}C$ values ($\delta^{13}C_{18:0}$ - $\delta^{13}C_{16:0}$) have been mainly used. The latter better allows to separate animal fats removing the environmental signal, allowing differentiation between the fats of major domesticates (Mottram et al. 1999). Worth to note is that the modern equine fats used for the production of the template plots, mainly comes from the Kazakhstan (Stear 2008; Outram et al. 2012); therefore assigning an equine fats origin to an extract is more challenging.

5. Results

Approximately 75% of the analysed prehistoric potsherds contained extractable lipid residues. Typical gas chromatographic profiles of the lipid residues displayed in Figure 4 show that the $C_{16:0}$ and $C_{18:0}$ fatty acids predominate, the high abundance of the latter confirming that the residues derive from animal fats (e.g. Evershed et al. 2002). Also abundant were saturated branched-chain and odd-carbon number fatty acids, including $C_{15:0}$, $C_{15:0br}$, $C_{17:0}$ and $C_{17:0br}$, components of bacterial origin diagnostic of both ruminant animal products (Hubbard & Pocklington 1968; Christie 1978) and/or equine adipose products (Hintz 1994; Pond et al. 1995). TAGs and their degradation products (DAGs and MAGs) were observed in 14% of the residues (examples are showed in Figure 4b,c,d). Finally, two extracts showed mid-chain ketones (one example is displayed in Figure 4f), suggesting that the vessels were heated to ca. 300°C required for their formation (Evershed et al. 1991; 1995; Christie 2012).

The $\Delta^{13}C$values derived from the Mid-Eneolithic potsherds are displayed in Figure 5 to allow a better comparison between different palaeo-ecosystems (Mid-Eneolithic steppe and forest-steppe sites of Dereivka, Molyukhov Bugor and Mikhailovka I). While, $\Delta^{13}C$ values derived from potsherds dating to the Late-Eneolithic and Early Bronze Age and located in the steppe (Mikhailovka II, III, Nizhniy Rogachik and Generalka sites) are shown in Figure 6.

Figure 5a,b reveals that an appreciable number of residues from Dereivka and Molyukhov-Bugor exhibit $\Delta^{13}C$ values characteristic of equine products. Ruminant adipose products were identified in four

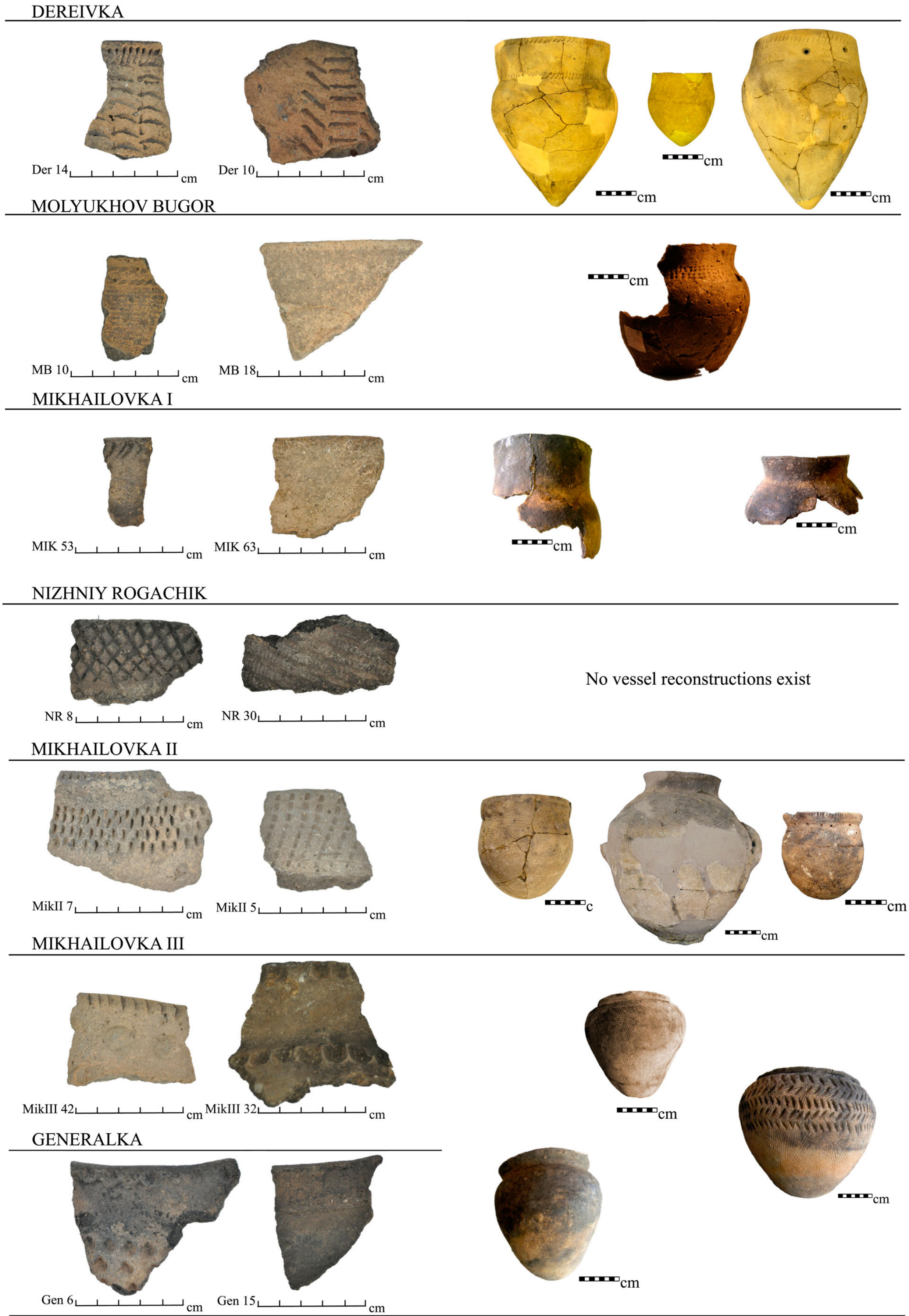

Figure 2. Examples of sherds and vessel shapes analysed in the current research.

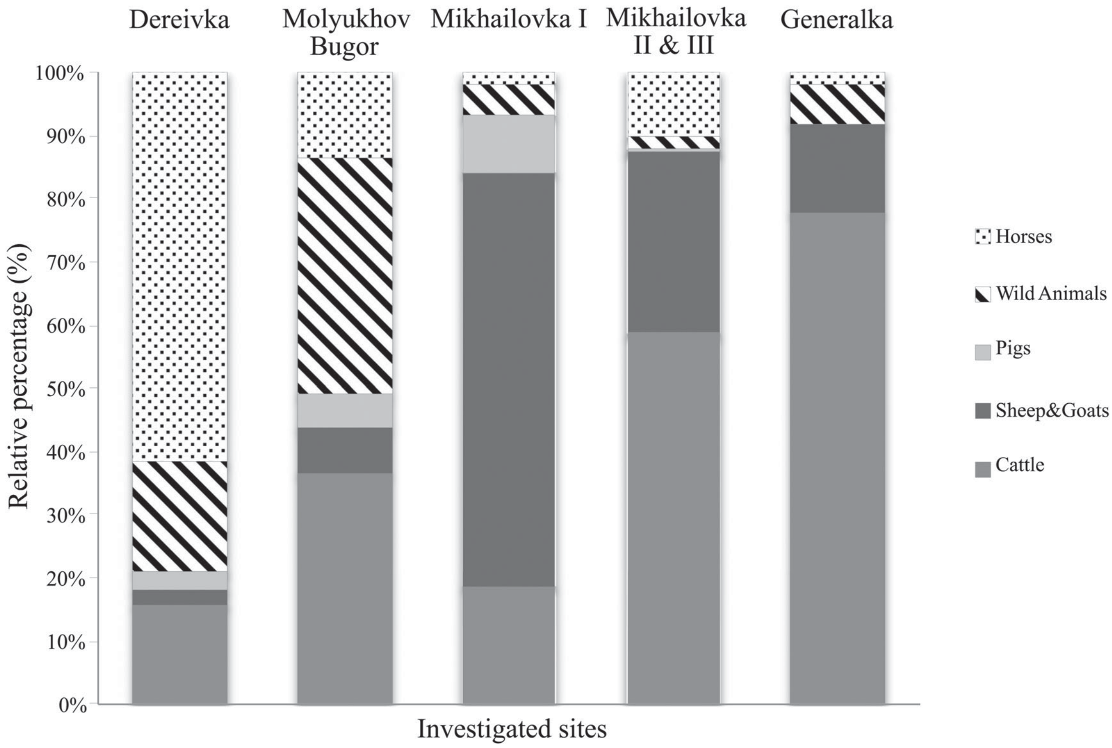

Figure 3. Relative proportions (NISP%) of the different classes of animals inferred from faunal records in Dereivka (Telegin 1986); Molyukhov-Bugor, (Bibikova 1963; Zhuravlev and Markova 2000; Zhuravlev 2008), ; MikhailovkaI, II and III (Bibikova and Shevchenko 1962) and Generalka (Kaiser 2010; Tuboltsev 2006).

and three residues respectively. Only one Dereivka residue suggests a weak dairy fat contribution and one extract from each site exhibited carbon isotope composition of non-ruminant (porcine?) products (Mukherjee et al. 2007). Finally, five Dereivka residues suggest a possible freshwater fish oil origin (Mileto et al. 2017). Based on mixing models (all displayed in the Appendix) the remaining three extracts have possible mixed origin.

The Mid-Eneolithic Mikhailovka extracts are very different from the two forest-steppe sites. Figure 5c displays n = 32 residues with $\Delta^{13}C$ values characteristic of ruminant adipose products, of which seven display $\Delta^{13}C$ values characteristic of ruminant dairy products. Equine products were present in one residue; one displayed a mixed origin.

$\Delta^{13}C$ values derived from potsherds dated to the Late-Eneolithic and Early Bronze Age steppe sites of Mikhailovka II, III, Nizhniy Rogachik and Generalka sites are shown in Figure 6. This comparison offers a new subsistence/diet reconstruction of the people steppe through time. Examination of Figure 6a reveals that the majority of Mikhailovka II residues (n = 11) exhibit $\Delta^{13}C$ values characteristic of ruminant adipose products, of which two residues have a dairy fat origin. Seven residues exhibit $\Delta^{13}C$ values characteristic of equine products and only one extract might have a freshwater fish oil origin.

Figure 6b reveals that the majority of Nizhniy Rogachik residues (n = 14) exhibit $\Delta^{13}C$ values characteristic of ruminant adipose products, of which five residues have a dairy fat origin. Six residues exhibit $\Delta^{13}C$ values characteristic of equine products, while only two extracts exhibit values consistent with a freshwater fish origin. The remaining extract appears to have a mixed origin.

Examination of Figures 6c reveals that the majority of Mikhailovka III extracts (n = 11) exhibit $\Delta^{13}C$ values characteristic of ruminant adipose products, of which four residues have a dairy fat origin. Two residues exhibit $\Delta^{13}C$ values characteristic of equine products and only one extract might have a freshwater fish oil origin. Finally, based on the mixed plots (in the Appendix) the remaining two residues (white dots) have possible mixed origin.

Finally, examination of Figure 6d reveals the majority of Generalka extracts (n = 18) exhibit $\Delta^{13}C$ values characteristic of ruminant adipose products, of which one residues has a dairy fat origin and four residues might have a weak dairy fat contribution ($\Delta^{13}C$=-2.6‰). Seven residues exhibit $\Delta^{13}C$ values characteristic of equine products, and only two extracts might have a freshwater fish oil origin.

It is worth noting the peculiar enrichment in $\delta^{13}C_{16:0}$ values in some residues possibly suggesting increasing C_4 plants in the ecosystem or operation of another enrichment phenomenon. The latter is associated with the residues of ruminant origin and specifically with a ruminant dairy origin, and it is more evident at the steppe sites (Figure 5, c and Figure 6). The increase might be related to a seasonal effect and

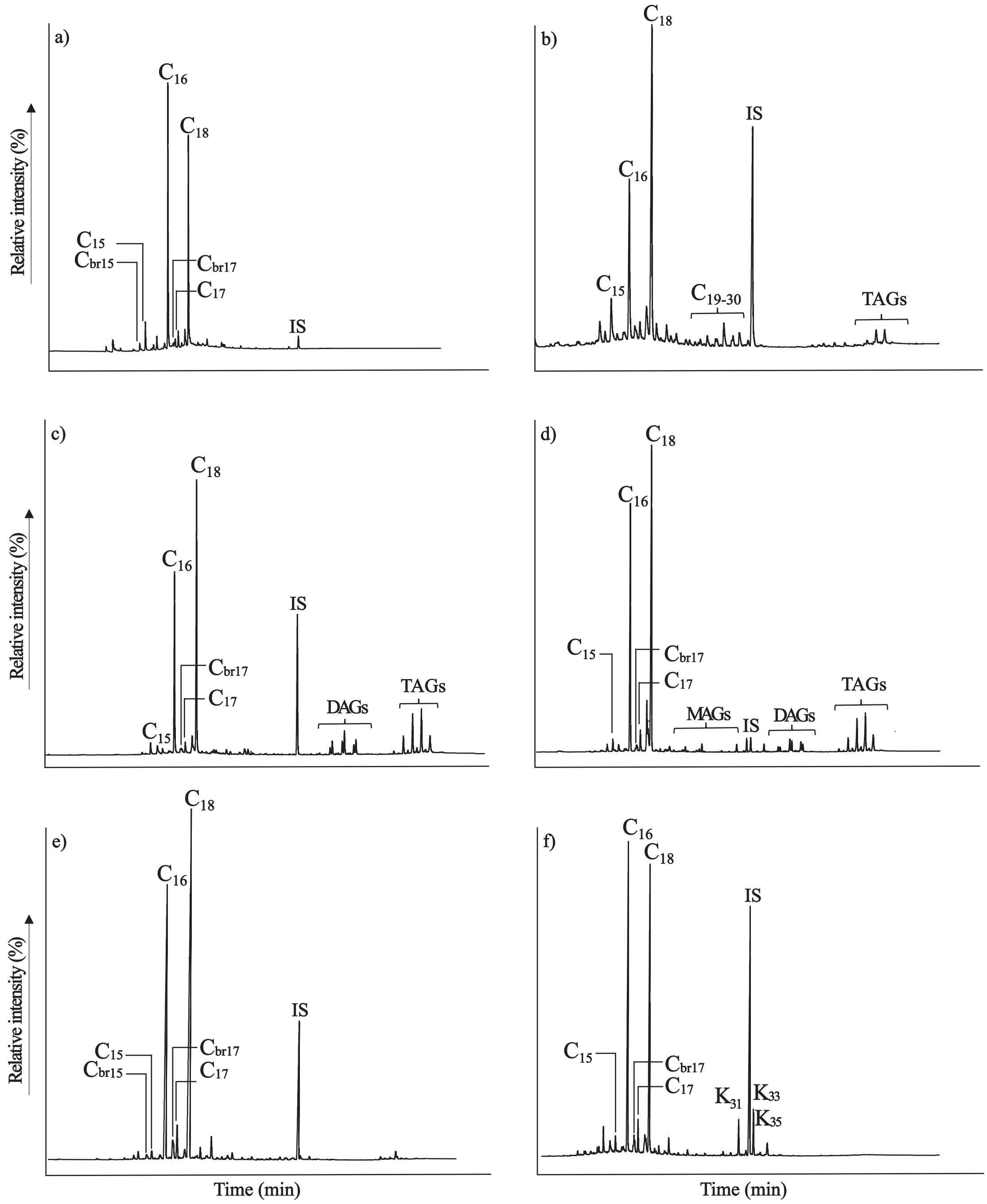

Figure 4. Partial gas chromatograms of total lipid extracts from pottery from: (a) Dereivka; (b) Molyukhov-Bugor; (c) Mikhailovka I; (d) Nizhniy-Rogachik; (e) Generalka; and (f) Mikhailovka III. Abbreviations: fatty acids (C); C_N, fatty acids with N carbon atoms; K, mid-chain ketones with 31, 33 and 35 carbon atoms; MAGs, monoacylglycerols; DAGs, diacylglycerols; TAGs, triacylglycerols; and IS, internal standard (*n*-tetratriacontane). Sample reference numbers: a, DER16; b, MB17; c, MIK68; d, NR20; e, GEN13; f, MIK14.

it might suggest that the ruminants exploited in the steppe were fed with C_3 plants but with some isotopically heavier, possibly C_4 plants, input especially during the summer as they usually give birth in spring so the production of milk is strongly connected to summer. However, the enrichment can also be explained by greater summer aridity, so it might derive from water-stressed C_3 plants (Evershed et al. 2008). Finally, seasonal pastoralism can also be hypothesised as the populations of the North-Pontic steppe are believed to practise it (Rassamakin 1999). However, considering the significance of this topic, this phenomenon will need to be addressed in a future paper, taking into account other climatic and environmental evidence.

6. Comparing faunal and organic residue evidence

6.1. Contemporaneous sites from different environments

Overall, the subsistence economy of the Dereivka community was based on horse exploitation as equine products prevailed in 48% of the extracts (Mileto et al.

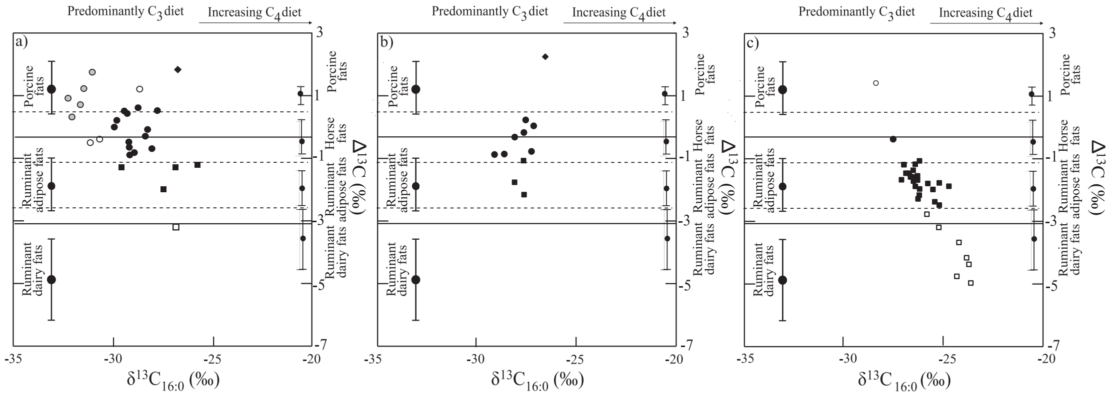

Figure 5. Scatterplots of δ^{13}C values of $C_{16:0}$ fatty acid against the Δ^{13}C values ($\delta^{13}C_{18:0}$ - $\delta^{13}C_{16:0}$) extracted from pottery vessels from (a) Dereivka, (b) Molyukhov-Bugor and (c) Mikhailovkal. In the figure: equine fats (dots); ruminant adipose fats (filled squares); ruminant dairy fats (empty squares); freshwater fish oil fats (grey dots); non-ruminant (porcine?) fats (rhombus) and mixed fats (empty dots). The template plot was created using the modern fats collected from animals raised in Britain; France; Kazakhstan; Switzerland; Turkey; Kenya and Libya (Copley et al. 2003; Spangenberg, Jacomet, and Schibler 2006; Stear 2008; Gregg et al. 2009; Outram et al. 2009; Dunne et al. 2012; Salque 2012; Salque et al. 2013). The δ^{13} C values obtained for the modern reference fats were adjusted for post-Industrial Revolution effects of fossil fuel burning by the addition of 1.2‰ (Friedli et al. 1986). Analytical precision is ± 0.3‰ (Adapted from Stear 2008; Salque 2012).

2017). The latter result reflects the faunal assemblage (Figure 7), of which horses dominated (60% NISP). Additionally, according to the faunal records, ruminant hunting was a widely practiced activity, as deer and elk comprised 75% the total wild animal assemblage (Kaiser 2010); domesticated ruminants (mainly cattle; 15%) were also exploited. Ruminant products exploitation is confirmed by the carbon isotope results, which revealed that 19% of the investigated pots were used to process ruminant fats. Finally, fishing was practiced as evidenced by both faunal records (3% NISP) and the carbon isotope results (18% of the total extracts have a freshwater fish origin). However, the detection of C_{20} and C_{22} APAAs as biomarkers for unsaturated fats, would have further confirmed the processing of aquatic resources in pots (Cramp et al. 2014). Nevertheless, the latter suggestion is also supported by the other researches (e.g. Lillie, Budd, and Potekhina 2011) From these data it appears that Dereivka subsistence economy was mainly based on horse exploitation associated with complementary activities including ruminant hunting, fishing and cattle breeding. However, it was not possible to infer from these data whether the horses were wild or domesticated (Outram et al. 2009; Mileto et al. 2017).

The subsistence economy of the neighbouring site of Molyukhov Bugor was more challenging to reconstruct. Interestingly, the compound-specific stable carbon values of the fatty acids in the pottery from Molyukhov Bugor were dominated by equine products (67%); however, the faunal records revealed a lower percentage of equine bones (14%). The latter mismatch can be explained as follow: (i) the mixture of materials due to the peculiar type of soil (*Chernozem*) might have altered the faunal assemblage, or (ii) equine products were preferentially processed in vessels while other animal products were processed in other ways (e.g. using a spit over an open fire). According to the faunal records hunting was a widespread activity as the 37% of the faunal assemblage comprised wild animals. In addition, the 44% were attributed to domesticated ruminants (including cattle, sheep and goats) suggesting that ruminant breeding was a significant complementary practise, also supported by the fatty acid carbon isotope values that suggest 25% of the lipid residues in pottery to have a ruminant origin.

A completely different economic pattern is suggested by the distribution of carbon isotope values of Mikhailovka I pottery extracts, where the majority of the Mikhailovka I vessels (94%) were used to process ruminant products, of which the 21% were used for the processing of ruminant dairy products. The latter result is unsurprising considering that ca. 90% of the faunal assemblage comprised ruminant domesticates, including: cattle, sheep and goats (Telegin 1986: 88 *ref.* Bibikova & Shevchenko 1962). As a result, considering both faunal and carbon isotope results, it appears that the inhabitants of the Mikhailovka I settlement were ruminant breeders, mainly specializing in sheep and goat herding (65% of the fauna records comprised small ruminants) and with a sophisticated knowledge of domestication as secondary products were clearly exploited. The equine bones comprised a very small proportion (2%) of the assemblage, which is reflected in the fats recovered from the pottery (3%). Significantly, these data revealed that the economic strategies of the three Mid-Eneolithic sites were autonomous, following the specific needs of the community and, more likely, the resources offered by the local environments. In summary, according to the existing faunal records (Kaiser 2010) and the lipid residue evidence, during the Mid-Eneolithic the forest-steppe people were

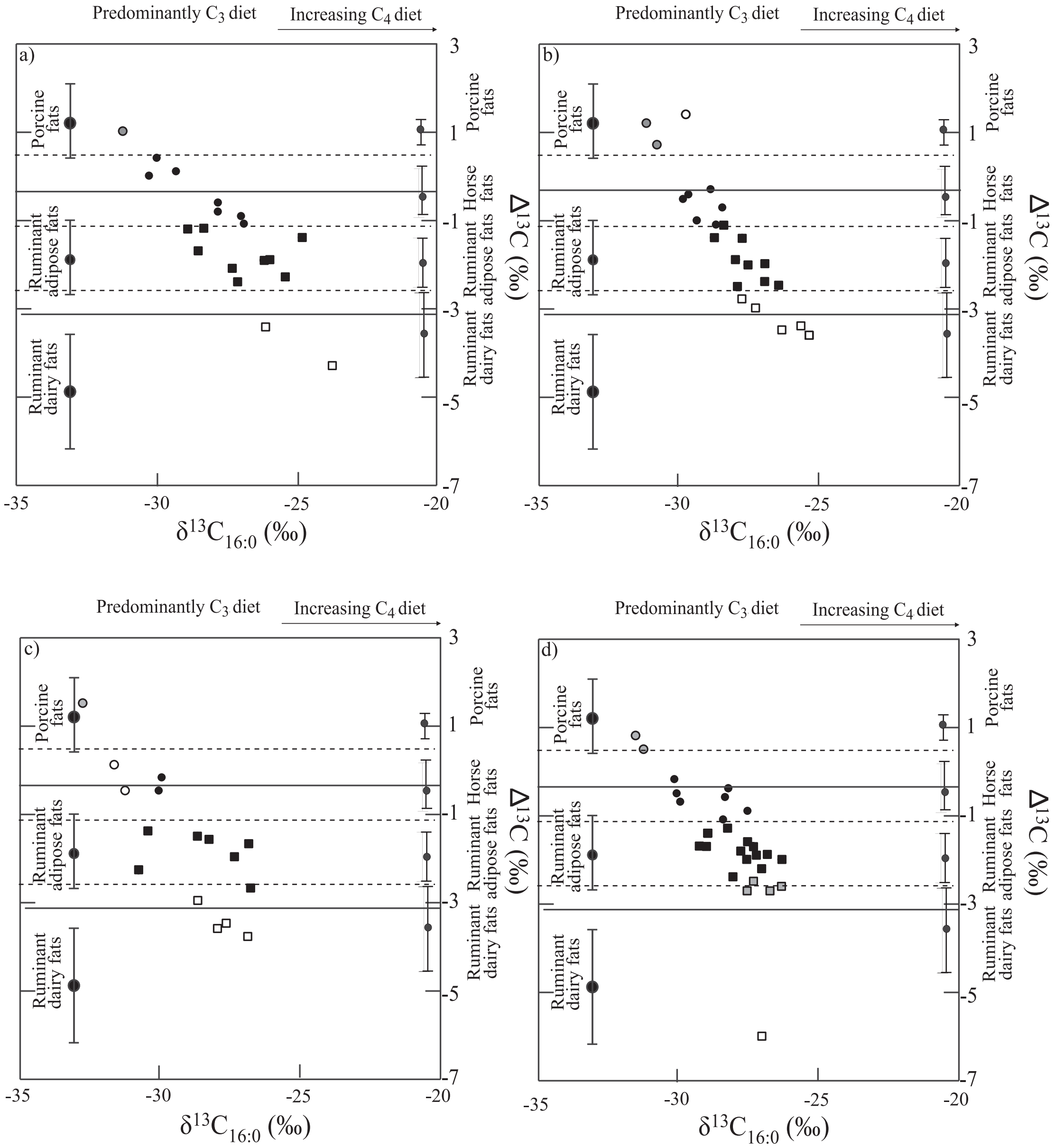

Figure 6. Scatterplots of $\delta^{13}C$ values of $C_{16:0}$ fatty acid against the $\Delta^{13}C$ values ($\delta^{13}C_{18:0}$ - $\delta^{13}C_{16:0}$) extracted from pottery vessels from (a) MikhailovkaII, (b) Nizhniy-Rogachik, (c) MikhailovkaIII and (d) Generalka. In the figure: equine fats (dots); ruminant-adipose fats (filled squares); ruminant-dairy fats (empty squares); freshwater-fish oil (grey dots) and mixed fats (empty dots). For the details concerning the template plot see the capture of Figure 5.

probably not pastoralists, while, in contrast, the steppe people of Mikhailovka appear to have adopted a full pastoral economy.

6.2. Subsistence economy in the steppe sites from the 4th to the 3rd millennium BC

The information obtained from existing archaeozoological records and the new molecular and stable isotope analyses reveal that the steppe dietary habits of Eneolithic and Early Bronze Age communities were ruminant-based. Interestingly, the great majority of the pottery vessels recovered from the steppe sites were used for the processing of ruminant carcass and dairy products, reflecting the faunal records (Figure 7), which are dominated by domesticated cattle, sheep and goats (Kaiser 2010). However, Generalka slightly departs from this trend producing only tentative evidence for dairying. Interestingly, the predominance of cows over bulls in Generalka faunal record and the high number of bones attributed to animals in the 36-48 months slaughter age range (internal report by Tuboltsev), suggests an economy mainly based on meat and dairy production, possibly indicating that the selection of the ceramic fragments may have biased interpretations.

Furthermore, based on compound-specific carbon isotope analysis of fatty acids, the non-ruminant residues recovered from the steppe potsherds, were possibly attributed to: (i) freshwater fish oils, suggesting that the steppe populations also practised fishing as a secondary activity, and (ii) mixing of commodities

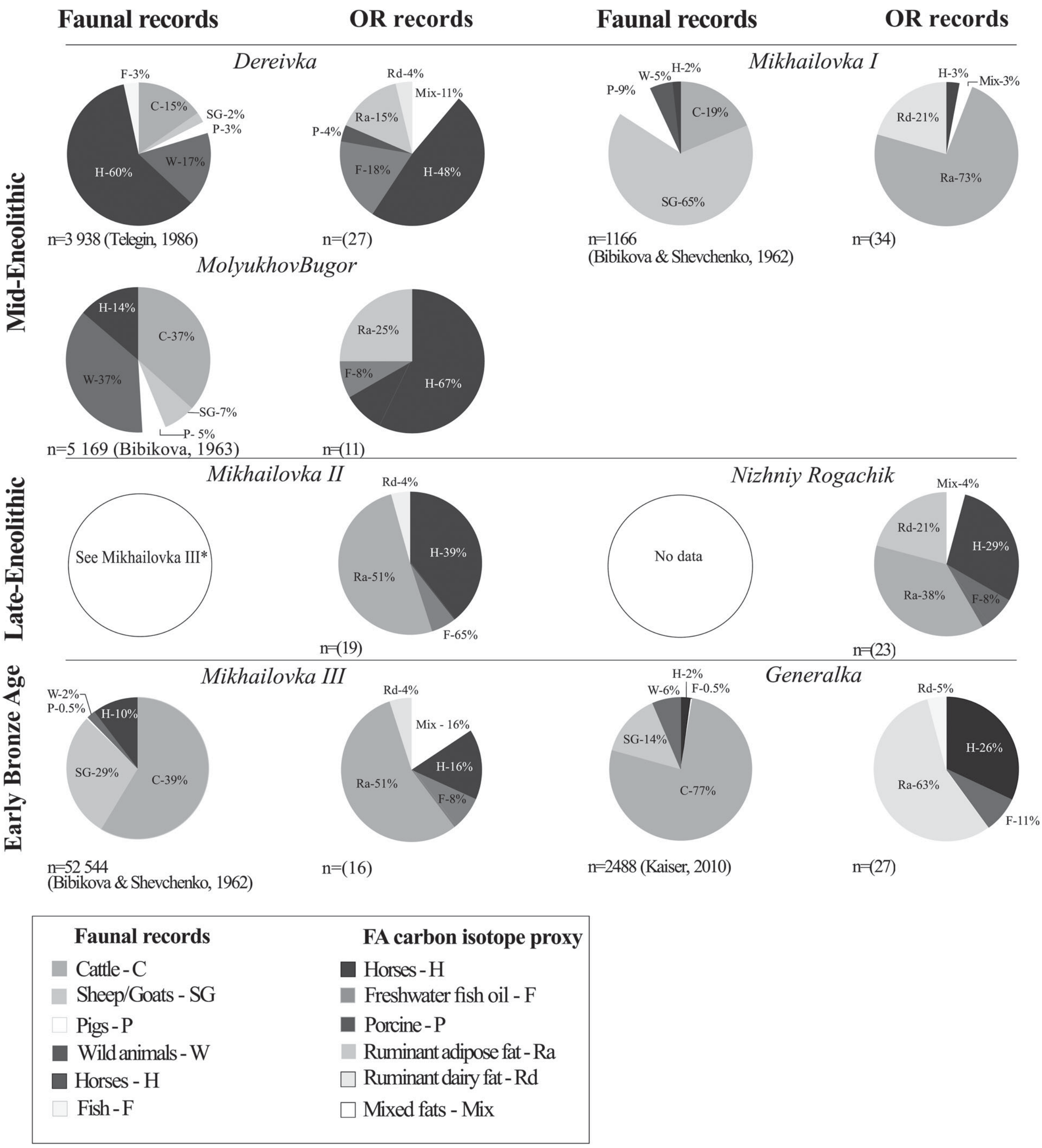

Figure 7. Comparison of faunal and organic residues records (OR records). Pie charts of the percentage of bone finds recognized as being horses, cattle, sheep/goats, pigs, wild animals and fish are illustrated adjacent to pie charts of the percentage of animal-fat-containing extracts from each of the sites (i.e. sherds containing plant lipids are not included, nor are sherds that did not yield any lipid). Total number of bone finds and lipid extracts are given at the base of the pie charts. Abbreviations: Horses (H); Freshwater fish oil (F); Ruminant adipose (Ra); Ruminant dairy (Rd); Porcine/Pigs (P); Wild animals (W); Cattle (C); Sheep and Goat (SG).

was also observed suggesting non-specialised use of vessels. However, despite the attempt to identify biomarkers for fish including the C_{20} and C_{22} APAAs as biomarkers for unsaturated fats, the absence of these biomarkers in the extracts, do not allow confirmation of the presence of freshwater fish oil. Generally, the exploitation of horses appears to be secondary, but appreciable especially in Nizhniy Rogachik, Generalka and Mikhailovka III communities.

Significantly, these data revealed that the economic strategies of the communities lived in the steppe were similar and based on extensive pastoralism of ruminants and exploitation of secondary products confirming that from the Mid-Eneolithic onward (Mikhailovka I site, discussed in the previous section) the steppe people possessed a sophisticated knowledge of animal domestication. Furthermore, the lipid residue findings did not reveal significant changes in the type of animal products recovered from pots. The main transformation relates the faunal records that revealed an increasing percentage of cattle bones in the later sites (Figure 3), which might suggest a transition from a highly mobile pastoral economy to a more sedentary one, as cattle are usually more exploited by settled communities (Kuzmina 2003, 208; Renfrew 2002, 2). However, this contradicts suggestions of an increasing nomadic pastoralist economy from the 3rd millennium BC onward (Anthony 2007). Since, the results presented herein cannot provide a definitive answer to the latter question, resolution will have to await future investigations.

7. Conclusions

This research provided significant new insights into the communities lived in the North-Pontic region during the transitional periods of the Eneolithic and the Early Bronze Age. The main findings are that:

(1) There was a considerable variation of animal exploitation in the forest-steppe sites compared to the steppe sites, confirming the results of previous researches (Outram et al. 2012; Lillie, Budd, and Potekhina 2011).
(2) Despite the complications (i.e. peculiar soil and mixed archaeological layers), the zooarchaeological analyses are largely consistent with the lipid residue findings.
(3) The lipid residues revealed that ruminant dairy products were exploited by the communities of the steppe from the Mid-Eneolithic period (MikhailovkaI site). This suggests that these communities were pastoralists possessing a sophisticated knowledge of animal domestication. According to the zooarchaeological record for this site, animal husbandry became the primary subsistence strategy in the 4th millennium BC. At first, the livestock consisted mainly of sheep and goats, with a shift to cattle only detected with appearance of the Yamnaya culture (3100 BC onwards).
(4) The forest-steppe appears to have been populated by hunters-fishers as the two investigated sites (Molyukhov-Bugor and Dereivka) displayed a predominance of wild animals, fish and horse remains (Rassamakin 1999; Lillie, Budd, and Potekhina 2011).
(5) The Molyukhov-Bugor site revealed a higher percentage of cattle bones and lipid residues of ruminant origin, suggesting that dietary habits were more varied compared to Dereivka, further suggesting that specialised substance practices can exist between sites even within the same, or similar, region. The latter dietary difference can be explained by a possible greater influence of the Tripolye culture to the closer Molyukhov-Bugor community, a suggestion also supported by the greater number of Tripolye imports discovered in Molyukhov-Bugor in comparison to Dereivka.
(6) Significant exploitation of horses was confirmed in the region. The lipid residues revealed that the two Mid-Eneolithic forest-steppe communities exploited horses extensively. The steppe communities also exploited horses but to a much lesser degree.
(7) Finally, a curious enrichment in $\delta^{13}C_{16:0}$ values toward heavier carbon isotope values (increasing C_4 plants?) was detected, especially associated with the residues with a ruminant dairy fat origin. The latter might be related to a seasonal effect and/or to greater summer aridity (Evershed et al. 2008) and/or seasonal pastoralism (Rassamakin 1999).

In conclusion, this research is the first interdisciplinary investigation of diet and subsistence strategies of the human groups that lived in the North-Pontic region during the Eneolithic and Early Bronze Age. Significantly, the application of compound-specific carbon isotope analysis of organic residues extracted from prehistoric pots, associated with existing archaeological evidence, has demonstrated that studies applied in the prehistoric North-Pontic region must consider the regional environmental variation as each subsistence economy was highly influenced by the specific local environment.

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Disclosure Statement

No potential conflict of interest was reported by the author(s).

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